Assessment of a contrast medium as an adjunct to endodontic radiography

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Abstract

Bedford JM, Martin DM, Youngson CC. Assessment of a contrast medium as an adjunct to endodontic radiography. *International Endodontic Journal*, **37**, 806–813, 2004.

Aim To assess if a contrast medium improved diagnostic yield of endodontic radiographs.

Methodology Forty-five extracted mandibular premolar teeth were radiographed in bucco-lingual and mesio-distal planes. Access cavities were prepared, pulpal tissue extirpated and Ultravist® contrast medium introduced under pressure. Radiographs were retaken and the teeth cleared following perfusion with India ink. Three examiners assessed all the films for: number of roots, number of root canals, curvature of root and/or root canal, presence of lateral canals, presence of a single foramen or apical delta and the presence or absence of canal obstructions. The examiners' interpretations were compared with the anatomy revealed by clearing.

Results Kappa scores were calculated for each of the examiners, for each set of radiographs, to assess the level of intra- and inter-examiner agreement. Only moderate agreement was found throughout ($\kappa = 0.40$–0.61). For multiple root canals a false-positive result was significantly more likely with contrast ($P < 0.05$). The use of contrast did not significantly improve the sensitivity of diagnosis of lateral canals or a single apical foramen. Contrast significantly increased the risk of falsely perceiving lateral canals ($P < 0.002$). Overall there was no statistically significant difference in the overall assessment of the anatomy of the root canals using contrast or plain radiographs ($P > 0.2$).

Conclusions Plain film radiographs confidently predict the presence of root or canal curvature but apical anatomy was assessed accurately in only 46% of cases. Plain radiographs were insensitive in assessing the number of root canals present, the presence of lateral canals and the occurrence of canal obstructions. The use of Ultravist® contrast medium to improve diagnosis of root canal morphology of premolars is not supported.

Keywords: contrast medium, radiography, root canal anatomy.

Received 21 April 2004; accepted 16 July 2004

Introduction

The radiograph is a fundamental part of endodontic practice with some 3.6 million endodontic radiographs taken by NHS dentists in the UK in 1999–2000 (Dental Practice Board, UK, personal communication, 2004). However, studies have shown that radiographs often fail to provide the basic information that is required such as the number of canals within the tooth or the presence of lateral canals.

Nattress & Martin (1991) reported that traditional techniques for identifying the number of root canals in mandibular anterior teeth failed to diagnose 30% of twin root canals. The information contained on a radiograph is interpreted rather than read and this interpretation can be open to bias from many sources. It has been noted that none of the technical aspects of radiology such as image quality or anatomical site can

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account for the large variation in radiographic interpretation (Zakariasen *et al.* 1984). The radiograph may portray the information required but often the interpretation of that information is flawed. It has been reported that six examiners asked to grade root canal treatments as successes or failures failed to agree in over 50% of cases (Goldman *et al.* 1972). The problem of poor examiner reliability is not limited to endodontic radiology; there is variation in the sensitivity of bitewing radiographs when viewed by several examiners (Ricketts *et al.* 1997) and in the past the diagnosis of chest conditions by radiography was shown to be inconsistent (Reger & Morgan 1970).

It is difficult to determine from a preoperative film if lateral canals are present or absent. Similarly any lateral canals demonstrated post-obturation may not represent the complete morphology.

There has been a previous report of the use of a radiopaque contrast media as an adjunct to plain radiography (Shearer *et al.* 1996). It was reported that this resulted in a greater inter-examiner reliability indicating an increased diagnostic validity. It was observed that the examiners were better able to agree on what they perceived the radiographic root canal anatomy to be. That study did not however, attempt to compare what the examiners assessed as being present from two sets of radiographs, with what the tooth root canal morphology actually was. There appears to have been few reports on this subject since then although the use of an adjunctive contrast medium (Hypaque®, Amersham Health Inc, Princeton, NJ, USA), in conjunction with 5% NaOCl and 17% EDTA – the 'Ruddle Solution' has been more recently highlighted in a standard endodontic text (Ruddle 2002).

The purpose of the present investigation was to assess the ability of experienced clinicians to determine the morphology of root canals from pre-treatment radiographs with, and without, the aid of radiopaque contrast medium injected into the root canal space. The accuracy of both methods was compared with the true canal anatomy revealed by a clearing technique.

Materials and methods

Forty-five extracted mandibular premolar teeth were collected from several general dental practices. The reason for extraction, the age of the patient and the past histories of the teeth were unknown. All of the teeth selected had mature apices, intact roots and none had undergone any form of endodontic treatment. Following extraction, adherent soft tissues were removed and the teeth were stored in 5% sodium hypochlorite solution.

Each tooth was radiographed in the bucco-lingual plane. The teeth were supported on an intra-oral E-speed film (Kodak Ltd, Hemel Hempstead, UK) using Dentina ribbon wax (Browning Plastics, Hull, UK). Radiographs were taken using a dental X-ray unit (Planmeca, Helsinki, Finland) at 7 mA, 70 kV, for 0.2 s. The focal spot to film distance was maintained at 30 cm. The tube angulation was 90° to the tooth and film. The films were processed automatically (Durr Dental DL26, Beitigham, Germany) using Kodak chemistry (Eastman-Kodak, Rochester, NY, USA).

Standardized endodontic access cavities were prepared using a high-speed handpiece with a diamond bur and water coolant. On location of the pulp chambers, gross pulpal debris was removed using barbed broaches. Apical patency was ensured using a size 8 or 10 K-file. Each tooth was placed in a solution of 5% sodium hypochlorite for 48 h to further eliminate pulpal debris.

The specimens were washed in water and dried using 27 gauge Endo-eze irrigating needles (Optident, Skipton, UK). The low osmolality iodinated, water-soluble, radiopaque contrast medium, Ultravist® 370 (iopromide) (Berlex Laboratories, Seattle, Washington, USA) was introduced into the root canal using the same style irrigating needles and a 10 mL syringe under hand pressure, until a jet of contrast medium was seen to emerge from the apical foramina. Each tooth was then radiographed in bucco-lingual and mesio-distal planes in the same manner as the pre-treatment views. Any teeth showing incomplete or patchy distribution of the contrast medium were re-infused and re-radiographed. The number of flushes required to achieve complete filling of the root canal system was noted for each tooth. The contrast medium was then flushed from the root canals with copious water and the teeth stored in individual, numbered glass vials.

The specimens were then infused with India ink (Winsor & Newton, Harrow, UK) for 7 days. Each tooth was then rinsed to remove excess ink and placed in 5% nitric acid solution. The specimens were checked daily and the solution refreshed until a fine gauge needle easily penetrated the softened specimen. These were considered suitably demineralized after 12 days. Following demineralization the specimens were dehydrated using 70, 90 and 100% alcohol solutions, each for 7 days. Once dehydrated, the teeth were rendered transparent using methyl salicylate.

This procedure was adapted from that described by Robertson *et al.* (1980). An independent assessment of the cleared teeth was to act as the gold standard for comparison with the radiographic assessment.

The radiographs with and without the Ultravist® (Contrast) were then separated into two groups and renumbered randomly to ensure blind assessment of the root canal anatomy. A record of the original numbers was maintained in order that comparison of the radiographic assessment could later be made with the assessment of the cleared teeth. Three experienced clinicians were first asked to view the standard pre-treatment radiographs. The radiographs were viewed on a viewing box using a viewer (X-Produkter, Malmö, Sweden) designed to mask out extraneous light. A magnification of 2.4 times was used. This system has been shown to produce optimal conditions for discerning fine detail (Welander *et al.* 1983). Curvature of a root or canal was defined as deviating >10° from a straight line using an extrapolation of the technique reported by Schneider (1971).

The following criteria were assessed:

1. Number of roots
2. Number of root canals
3. Curvature of root (yes/no)
4. Curvature of root canal (yes/no)
5. Presence of lateral canals (yes/no)
6. Presence of single foramen or apical delta
7. Presence of canal obstructions (yes/no).

Standardized assessment forms were produced. The radiographs of the teeth with contrast medium were randomly renumbered and their order changed. The same examiners reassessed the second set of radiographs using the same criteria. No training or calibration of the examiners took place. Examiners were unaware of the overall purpose of the study.

Each set of radiographs was renumbered, their order changed and then re-examined to measure intra examiner reliability.

Statistical analysis

From the examination of the radiographs both with and without the use of contrast medium a comparison of each group was made with the independent assessment of the dyed and cleared teeth. The cleared teeth acted as the reference indicating the true presence of lateral canals. The presence of the seven test parameters was assessed for each of the teeth. In order to reduce the problems encountered when multiple comparisons are made, it was decided to calculate the sensitivity and specificity of each radiographic method for the three parameters whose identification was most likely to be enhanced by the use of contrast medium. These were considered to be:

1. the presence of lateral canals,
2. the number of canals present,
3. the presence of a single foramen or an apical delta.

Additionally, a tooth was considered accurately assessed if all of the above conditions were correctly diagnosed and three of four of the other parameters were correct. The proportion of teeth correctly diagnosed in each group was calculated.

The sensitivity and specificity of the two groups of radiographs in assessing the desired variables were tested. In order to compare one type of radiograph with the other, McNemar's test was used to test the null hypothesis (Bland 1996). A value of $P < 0.05$ is usually considered statistically significant but with the introduction of several variables, a value of $P < 0.02$ was considered a significant result at the 95% level.

In addition to testing the specificity and sensitivity of the two tests, the degrees of inter and intra-examiner reliability for each method was assessed. Kappa scores were used to measure which of the two types of radiographs resulted in the higher level of agreement between the three clinicians and between their own first and second assessments of the radiographs.

Kappa scores were interpreted as follows (Eckerbom & Magnusson 1997): 0–0.2 = poor agreement, 0.2–0.4 = fair agreement, 0.4–0.6 = moderate agreement, 0.6–0.8 = good agreement, 0.8–1.0 = very good agreement.

Finally, the percentage of teeth shown by the clearing method to have lateral canals and the mean number of lateral canals found within the sample were calculated. These figures were then compared with those calculated from the results suggested by the examination of the two groups of radiographs.

Results

An example of the plain and contrast medium radiographs and cleared tooth of one specimen are shown in Fig. 1a–c.

Number of roots

All were correctly identified by all of the examiners each time they viewed the radiographs giving a sensitivity of 1. The specificity of this test was, by definition, 0.

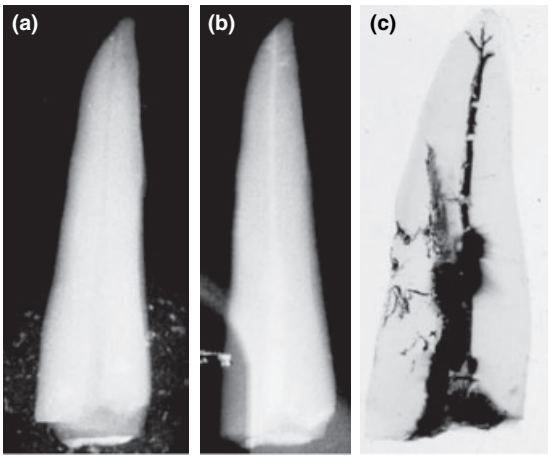

Figure 1 (a) Plain film, (b) contrast film (both from bucco-lingual direction) and (c) cleared mesio-distal view of the same specimen.

Number of canals

In assessing the presence of multiple root canals, the plain radiographs had a sensitivity of 0.12 and a specificity of 0.99 and the contrast medium radiographs showed a sensitivity of 0.10 and a specificity of 0.89 (Table 1). The difference in the sensitivity of the two tests was insignificant ($P > 0.2$) but that between the specificities was significant ($P < 0.05$). This suggests that both tests failed to show multiple root canals when they were present. With the plain radiographs, it was unlikely that an extra root canal was diagnosed (false positive) as being present when actually no such 'extra' canal existed. However, this risk was significantly increased in the contrast group.

Table 1 Comparison of plain and contrast films

	Plain film	Contrast film	Significance
Number of root canals			
Sensitivity	0.12	0.10	$P > 0.2$ (ns)
Specificity	0.99	0.89	$P < 0.05$
Number of lateral canals			
Sensitivity	0.16	0.10	$P > 0.2$ (ns)
Specificity	0.56	0.75	$P < 0.002$
Presence of lateral canals			
Positive predictive value	0.23	0.25	$P > 0.2$ (ns)
Negative predictive value	0.40	0.46	$P > 0.2$ (ns)

Number of lateral canals present

The plain radiographs showed a sensitivity of 0.16 and the contrast 0.10 ($P > 0.02$). The specificity of plain film was 0.56 and contrast 0.75 ($P < 0.002$) (Table 1). These results show that once again the examiners were unable to accurately assess the presence of a condition, in this case lateral canals. The plain views were significantly less likely to suggest that lateral canals existed when they did not.

Incidence of lateral canals

The actual number of teeth within the sample shown by clearing to contain lateral canals was 20. This represents 46% of the sample (0.73 lateral canals per tooth). The proportion of teeth reported as showing lateral canals after examination of the plain radiographs was 40% (0.62 lateral canals per tooth) and the contrast group 23% (0.28 lateral canals per tooth). Both of these levels of reported incidence are significantly different from the actual level ($P < 0.001$).

From this data it is possible to calculate the prevalence of lateral canals within the sample (0.455), and to estimate both the positive predictive value (PPV) and the negative predictive value (NPV) for the two tests. The PPV gives the probability that a tooth with a lateral canal will be correctly identified. Conversely the NPV gives the probability that a tooth without any lateral canals will be correctly classified.

Table 1 demonstrates that the PPV levels estimate that 23% of positive results from the plain radiographs would be true positives, in the case of contrast radiographs this figure would be 25%. The NPV results were 0.40 and 0.46 for the plain and contrast views, respectively. Thus approximately 40% of negative test results (no lateral canals present) would be true negatives. A Student's *t*-test on these proportions showed that no significant difference existed between the two groups of films ($P > 0.2$).

Diagnostic consistency

The degrees of inter and intra-examiner reliability for each of the groups of radiographs were assessed to examine which type of view was reported, correctly or incorrectly, most consistently. Kappa scores were calculated for each of the examiners, for each set of radiographs (Table 2). All of the examiners showed only moderate (0.41–0.60) agreement between their

Table 2 Intra- and inter-examiner agreement

	Plain film	Contrast film
Intra-examiner agreement (κ)		
A	0.56	0.58
B	0.44	0.59
C	0.45	0.41
Inter-examiner agreement (κ)		
A/B	0.52	0.48
A/C	0.51	0.59
B/C	0.45	0.31

first and second assessment of each group of radiographs (intra-examiner agreement). The level of agreement between each of the examiners when viewing the two groups of radiographs (inter-examiner agreement) was calculated. In order to simplify the statistical analysis, each examiner was compared with each of the others individually. Table 2 also shows that there was only a moderate level of agreement of the examiners with each other. On examination of the plain films A agreed with both B and C to a similar degree. C and B consistently showed less agreement with each other than with A. When viewing the contrast films, they only showed a fair degree of agreement. At the 95% level, there was no significant difference between the results of the observations made from the two groups of radiographs.

No statistically significant differences ($P > 0.02$) could be shown between the reporting of the two types of films with respect to the following parameters: single or complex apical foramen, curvature of the root, curvature of the canal, presence of an obstruction (accurately assessed in less than one-third of cases) or the proportion of teeth correctly assessed.

Discussion

The sensitivity and specificity results for the number of root canals and presence of a canal obstruction are very similar to those accepted for the use of bitewings in the diagnosis of occlusal caries (Ricketts *et al.* 1997). This suggests that the radiographs examined were useful in identifying when the condition was absent (multiple canals not present) but less useful in identifying those cases where an 'extra' canal or a canal obstruction may have been present. This fact may be useful in retreatment cases where the technical quality of a previous root treatment appears satisfactory, but it has failed. The ability to accurately discount the possibility of an extra canal would be clinically useful. If this could be ruled out as a cause of failure, the risk of iatrogenic damage associated with trying to locate the perceived additional canal would be removed. It is conceivable that some benefit may be gained by using this contrast solution in re-treatment cases. After removal of the previous root filling material, the tooth could be perfused with the medium in order to identify any anatomical variations that could be a cause for the failure of the initial treatment. Also on gaining access to the root canals, the contrast medium could be used to verify that the operator has correctly identified the canal morphology preoperatively.

The low sensitivity of a test can be explained by a low incidence of the condition in a sample but this was not the case in the present sample where the incidence of multiple root canals was 22.2% which is comparable with 25% reported by Vertucci (1978). The poor results for sensitivity for the number of canals, for both types of film can therefore be considered as disappointing, particularly as this is one of the main points to be assessed from a pre-treatment film. It should therefore be assumed that radiographs do not accurately depict the number of root canals present in an individual tooth and that normal variation should be assumed prior to commencing treatment. This point has been made previously (Nattress & Martin 1991).

More consistent results were obtained for the determination of apical anatomy. Where a complex apical arrangement (multiple foramina/apical delta) was present, the majority of cases were correctly assessed (specificity 0.71–0.81). This would lead the clinician to assume a complex apical anatomy and encourage them to use a technique suited to such a terminal morphology. The use of contrast medium, however, did not significantly enhance diagnosis of this feature and important information is available to clinicians from plain films if they are carefully studied.

The most sensitive of the tests were those for the assessment of curvature of the root and canal. It was unlikely that the examiners would miss the presence of curvature in either the root or the canal although this could depend upon both the plane and radius of the curve. The specificity of the two films were very similar for both tests, suggesting that it is equally likely, using both methods, that a straight canal would be mistakenly regarded as curved. The pre-curving of stainless steel instruments in these cases could lead to procedural errors such as zips, ledges or canal transportation during root canal preparation. This problem is less liable to occur with nickel titanium instruments (Song *et al.* 2004).

The opinions of the examiners on the presence of obstructions within the canals were similar for both groups of radiographs. It was unlikely that a true canal obstruction would be predicted. When no obstruction existed, the observers in approximately 90% of cases correctly stated this. The observers noted that the presence of air bubbles or soft tissue inclusions within the contrast medium made discrimination between true canal obstructions and artefacts difficult. In plain radiographs, the fine differences in contrast between calcified material in the canal and the pulp space were discernible but these were lost when the contrast was used.

Presence of lateral canals

The incidence of lateral canals was high (46%). This is comparable with one previous study (Kirkham 1975) where teeth were extracted in the presence of lateral periodontal pockets, but is higher than that shown by DeDeus (1975). Although it is unlikely, many of the current sample of teeth may have been extracted because of perio-endo lesions. As these are often associated with lateral canals (Zehnder *et al.* 2002) this could account for the high incidence of these.

Diagnostic consistency

Due to the inclusion of multiple variables and the fact that the two samples of teeth were not independent, the use of Kappa scores to decide the level of diagnostic reliability was not considered valid. Hence the proportion of teeth considered to have been correctly assessed was calculated and McNemar's test performed.

In another study utilizing a contrast medium within root canals (Shearer *et al.* 1996) three outcomes were possible:

1. both types of radiographic views gave the examiner an accurate picture of what was clinically present,

2. neither view accurately depicted the true anatomy or

3. one or other view more accurately depicted the true three-dimensional layout of the root canal space.

The results from the present study do not support the findings of Shearer *et al.* (1996). Whilst that study found very good inter- and intra-examiner agreement with the use of contrast in molars, the present results show only moderate levels of intra-examiner agreement and only fair levels of inter-examiner agreement. This may, however, have been due to a number of differences between the investigations: an increased number of examiners, premolars rather than molars and different features being assessed, different diagnostic criteria applied, and radiographic differences (plane of film and different contrast medium).

Procedural difficulties

Several problems were encountered whilst using Ultravist® in the manner described. The material is expensive and must be protected from prolonged exposure to light, hence the shelf life of the material is relatively short. The volume required to adequately perfuse a single tooth was approximately 5 mL. Only 12 (26%) of the teeth were assessed radiographically as completely perfused with media after the first attempt. This, despite the fact that the solution was injected under pressure and observed to emerge from the root canal orifices. Six teeth (13%) required more than three repeat applications and one required five. In the current study there was no method of determining whether any residual tissue that may have prevented perfusion of the contrast material into the canal was subsequently by-passed or stained by India ink during the clearing process.

Clinically, the ideal stage at which to introduce the contrast medium would be directly after having gained access to the pulp chamber. The clinician would then be able to visualize the root canal form prior to instrumentation of the canals. As the bulk of the contaminated material in an infected root canal system is to be found in the pulp chamber (Saunders & Saunders 1997) it would seem unwise to forcefully introduce the contrast medium into the canals before the initial stages of canal preparation are completed in order that infected material is not transported down into the root canal. It is also advisable to use methods, which minimize the introduction of the irrigant into the periapical tissues. Therefore, forcing Ultravist® into the canals and out of the apical foramina in order to ensure full perfusion cannot be recommended.

In our study, repeat radiographs were required to ensure the maximum penetration of contrast medium into the canals was achieved. The repeated exposure of patients in a clinical setting could not be justified unless the diagnostic value of the repeat films over the traditional views was very significantly improved. This was not the case in this study. One further drawback of the use of Ultravist®, which is confined to its use *in vitro*, is that it tends to accumulate in the cracks and fissures of the external root surface resulting in radiographic artefacts. This accumulation may help to explain the increased (but incorrect) perception of

additional canals in contrast medium radiographs. However, to minimize the risk of this occurrence, any contrast medium was cleaned from the external surfaces using damp tissues and then blotted dry.

Radiographic interpretation

All of the examiners described difficulties in assessing both the conventional and test radiographs. The assessment of the presence of lateral canals in both sets of films was reported as difficult. This is borne out by the low specificity and sensitivity scores achieved.

It would be reasonable to expect that when viewing radiographs of teeth outside the mouth, where no film distortion or anatomical features such as overlapping roots, bony trabeculae or soft tissues are present, that our interpretation of the films would be more accurate than in a clinical situation. On viewing the films it can be seen that any fine discrimination of the ramifications of the individual canals is made more difficult by the presence of the contrast which seems to obliterate the slight changes in contrast which clinicians learn to distinguish. This may explain the inability of the examiners to interpret fine details such as the presence of a lateral canal. This does seem to suggest that clinicians require some formal training in the assessment of radiographs used in endodontics to gain the maximum diagnostic information available.

Although the contrast medium radiographs were reported to be difficult to interpret, there was no statistically significant difference between the accuracy of the diagnosis made from them compared with the plain radiographs. It would seem that information additional to that obtained from a radiograph is required to complete the assessment of a tooth prior to commencing root canal treatment. The use of an apex locator in association with conventional radiographs has been advocated (Fouad 1993). Information additional to that available from a plain radiograph can be obtained from views produced by radiovisiography. The ability to enlarge the films has been shown to increase the sensitivity of radiographs, particularly when assessing the presence of lateral root canals (Scarfe *et al.* 1995).

Conclusions

It is possible from *in vitro* plain film radiographs to confidently predict the presence of root or canal curvature greater than 10°, in the plane of the film, in approximately 80% of cases.

The anatomy of the apical portion of the root canal was accurately assessed from plain films in only 46% of cases *in vitro*.

The use of plain radiographs alone, *in vitro*, to assess the number of root canals present, presence of lateral canals and the occurrence of canal obstructions has been shown by these results to be insensitive.

The use of Ultravist® contrast medium to improve the diagnosis of root canal morphology of premolars *in vitro* is not supported by this study.

Acknowledgements

The authors would like to thank Dr Brett Scaife, Department of Medical Statistics for his help in preparation of this manuscript.

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